# *Automation of Image Quality Evaluation for X-ray Non-Intrusive-Inspection Systems*

CASIS 2017

May 17, 2017

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LLNL-PRES-730962

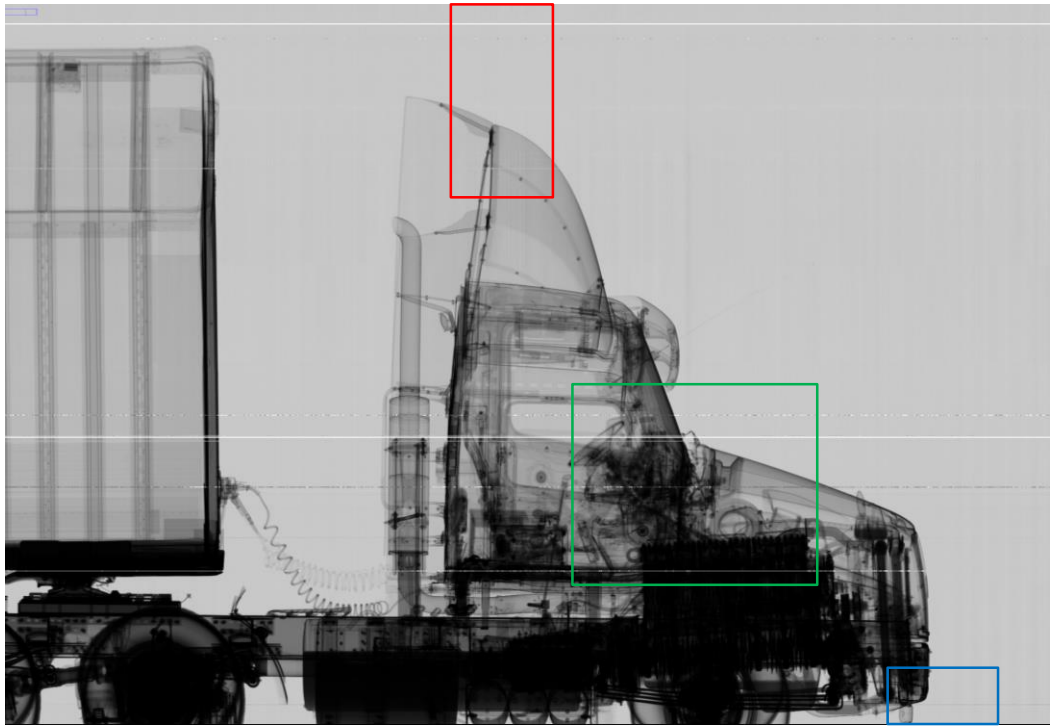
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

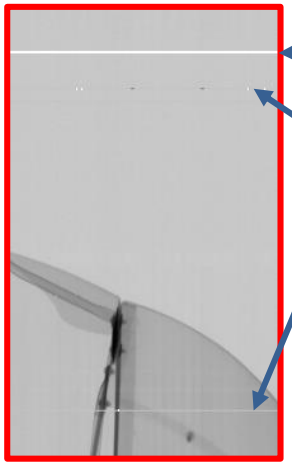
# Summary

- It is possible to automate the computation of image quality metrics for truck scanners
- We have written analysis software that will take an image and determine
  - Which detector elements are likely to be defective
  - The error weighted mean point spread function in the horizontal and vertical directions
- As expected
  - The lossy compression of JPEG images create artifacts that may be impossible to disentangle from point spread functions
  - PSFs for Non-Intrusive-Inspection systems (NIIs) that do not image perpendicular to the conveyance are difficult to assess
- Future work includes:
  - Wrapping the analysis code in an easy to use GUI,
  - Automatic processing of directories full of images, and
  - Dealing with additional imaging system artifacts

# Quality Metrics We Examined: Bad Detector Elements

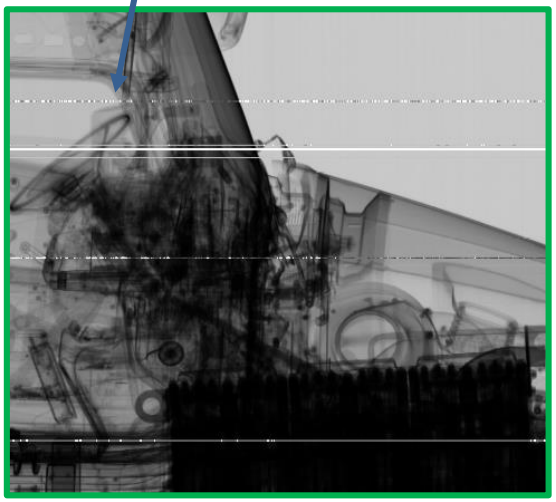
Bad detectors may be stuck bright, dark, or may be intermittent.





Stuck Bright

Intermittent



Stuck Dark

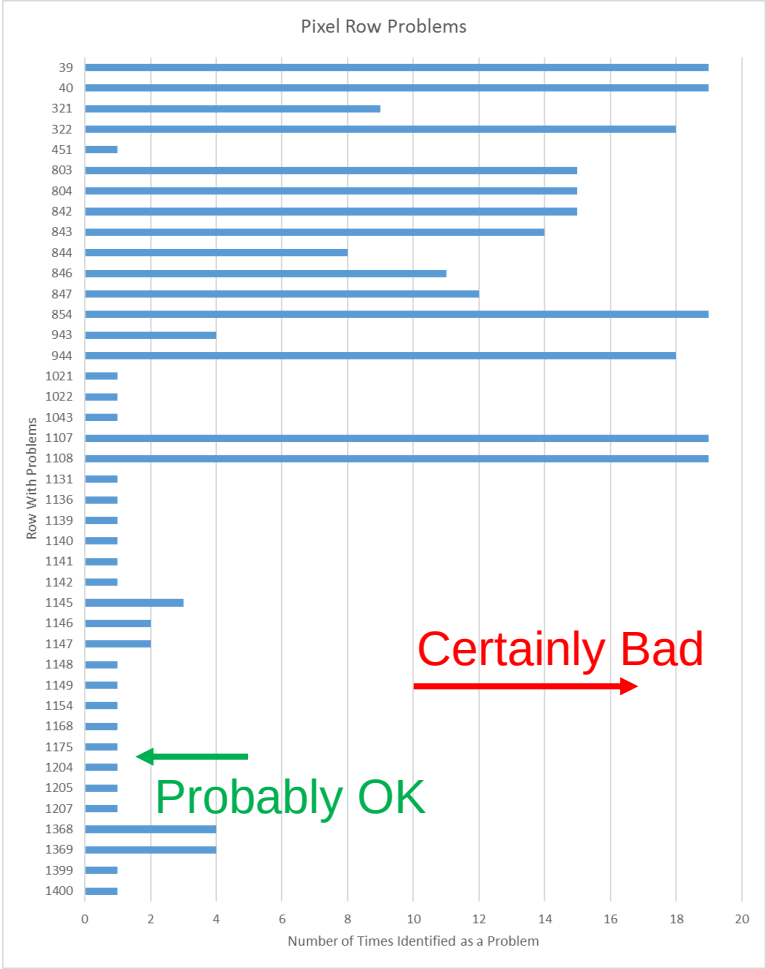
# Quality Metrics We Examined: Bad Detector Elements

- We find bad detectors by projecting the entire image along its rows.


- The spikes in the projection show where there are detectors that are bad.
- We can find the spikes in the projection by subtracting a median filtered version of the projection and looking for projected rows that have a value above a user chosen threshold.
- There are occasional false alarms with this technique when there are large transitions in the projection (i.e. going from air to cargo).

# Quality Metrics We Examined: Bad Detector Elements

- Because of the possibility of false alarm, it is necessary to acquire bad detector maps from several images and see which detectors show up repeatedly.
- One way to display this is as a chart showing the number of times a detector is identified as having problems. In the example at the right where there were 19 images processed, detectors with more than 10 instances are almost certainly bad, while detectors with less than 5 are probably not.



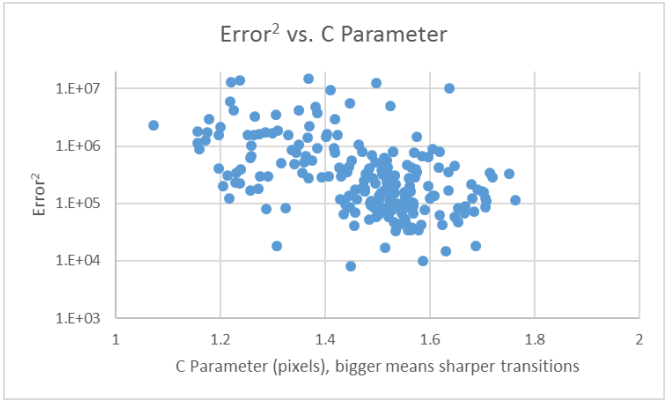
# Quality Metrics We Examined: Point Spread Function

- The other quality metric we examined was the point spread function. This was evaluated by fitting an error function (erf) to transitions in the image.
- Transitions are modeled as $y = A + B\ \mathrm{erf}(C(x - D))$, where $\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$.
- The transition model is the response we would expect from a sharp edge assuming a Gaussian point spread function.
- For each transition we determine the parameters *A, B, C* and *D.*
- The parameter *C* is the inverse of the width of the point spread function (i.e. PSF width = 1/C). Small PSF width (or large C) is better. A consistent PSF is a good indication of a well behaved system.

# Quality Metrics We Examined: Point Spread Function Choosing the transitions to model, creating a result

- Best transitions (light to dark, dark to light) appropriate for determining the PSF. Criteria are:
  - Low noise
  - High contrast
  - The model gives reasonable results (PSF is on order of spatial resolution of system)
- The analyst sets the parameters that determine the acceptable noise level and minimum contrast. Sharp transitions (fractions of the spatial resolution) are rejected.
- The error weighted mean of the C parameter determines the appropriate PSF (1/*C* parameter) from all the transitions that meet the acceptance criteria.
  - The error weighted mean of the *C* parameter is given by

$$C = \frac{\sum_{transitions} \frac{C}{error^2}}{\sum_{transitions} \frac{1}{error^2}}$$




  - For instance, the error weighted mean of the C parameter for the cluster of transitions shown in the graph is C = 1.53, thus PSF = 0.65 pixels.

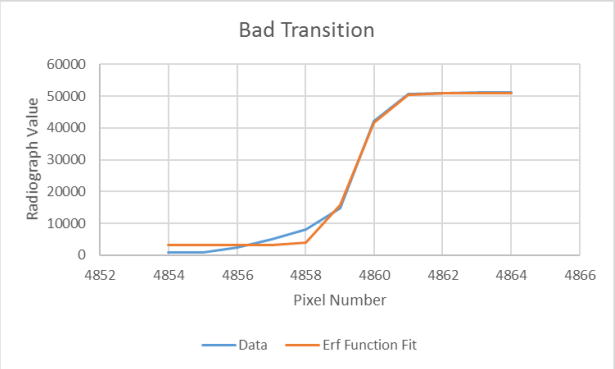
# Quality Metrics We Examined: Point Spread Function Evaluation of results from our algorithm

- For every transition that meet our criteria we determine if the Gaussian blur model is appropriate (small error).
  - Sometimes it is, and the error is small:

| Sample Horizontal MTF for row 1315 (Good Transition) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | 25414.05115 | | | | | | | |
| B | | | | -25334.68877 | | | | | | | |
| C | | | | 1.536234584 | | | | | | | |
| D | | | | 427.7260103 | | | | | | | |
| Error$^2$ | | | | 29036.21749 | | | | | | | |
| Pixel | 422 | 423 | 424 | 425 | 426 | 427 | 428 | 429 | 430 | 431 | 432 |
| Data | 50722 | 50763 | 50851 | 50668 | 50699 | 47839 | 14058 | 177 | 123 | 147 | 56 |
| Fit | 50748 | 50748 | 50748 | 50748 | 50744 | 47842 | 14055 | 222 | 79 | 79 | 79 |

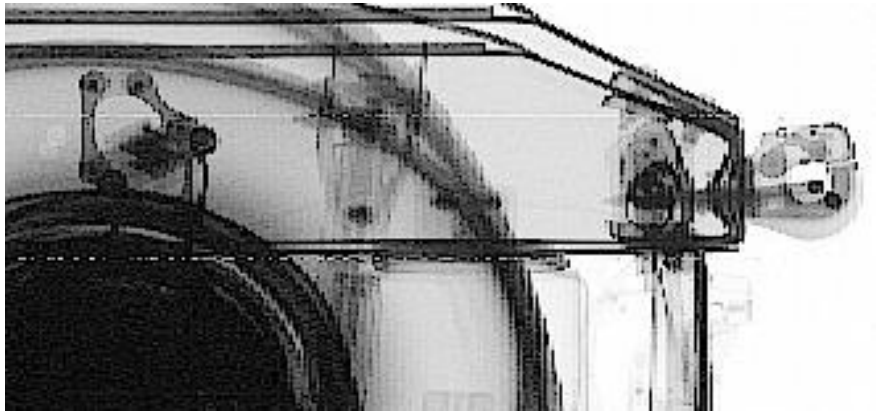

  - Sometimes it isn't, and the error is large:

| Sample Horizontal MTF for row 1397 (Bad Transition) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | | | 26957.73159 | | | | | | | |
| B | | | | 23884.54391 | | | | | | | |
| C | | | | 1.041570434 | | | | | | | |
| D | | | | 4859.417777 | | | | | | | |
| Error$^2$ | | | | 3.20E+07 | | | | | | | |
| Pixel | 4854 | 4855 | 4856 | 4857 | 4858 | 4859 | 4860 | 4861 | 4862 | 4863 | 4864 |
| Data | 800 | 978 | 2494 | 4948 | 8030 | 14831 | 42104 | 50729 | 50926 | 51145 | 51237 |
| Fit | 3073 | 3073 | 3073 | 3082 | 3951 | 15930 | 41500 | 50369 | 50838 | 50842 | 50842 |

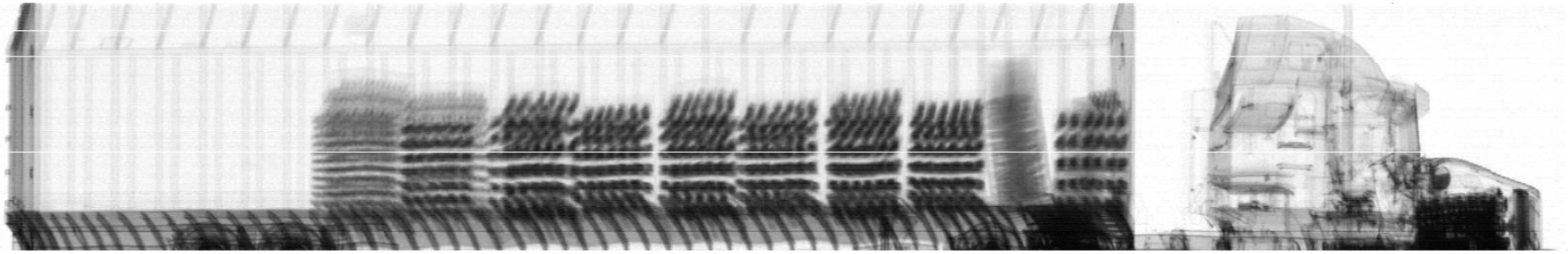


# Quality Metrics We Examined: Point Spread Function Things that make it difficult

- There are a number of factors that make measuring the point spread function difficult:
  - Image compression, e.g. lossy JPEG, artifacts (we never know if we're seeing the actual performance of the system, or an artificial sharpening or blurring due to the compression)

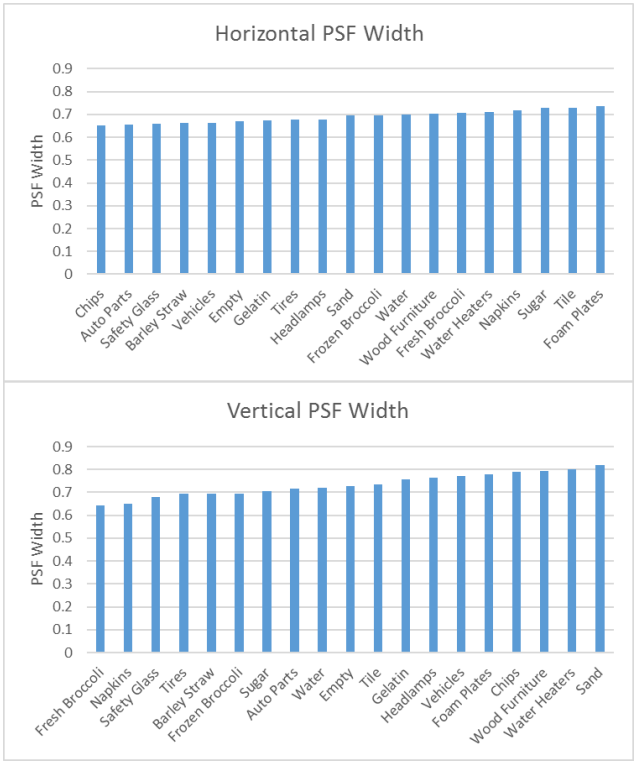


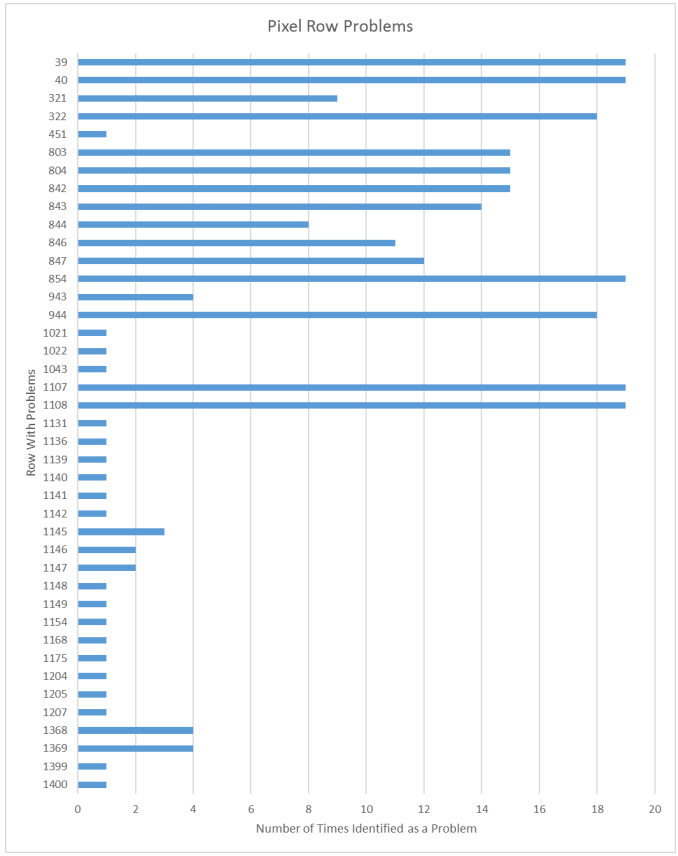
  - NIIs that do not image perpendicular to the conveyance, since their transitions are not sharp



# Presenting Analysis Results

- There are three sets of results we want to present as outputs for each evaluation
  - Problem Pixels
  - Horizontal PSF
  - Vertical PSF

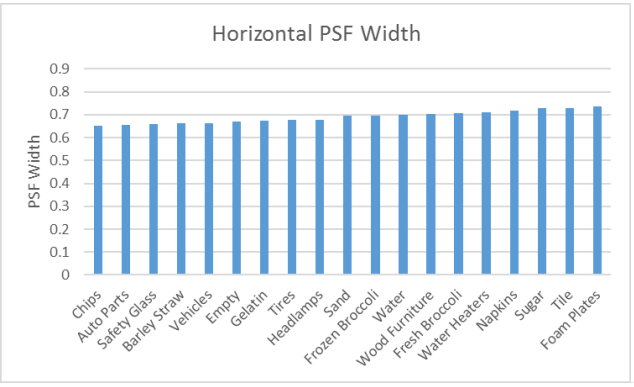


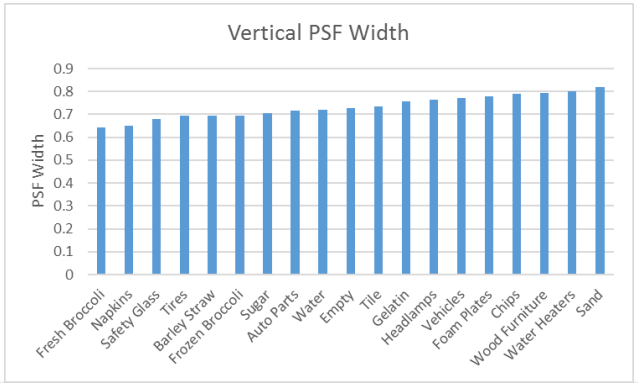



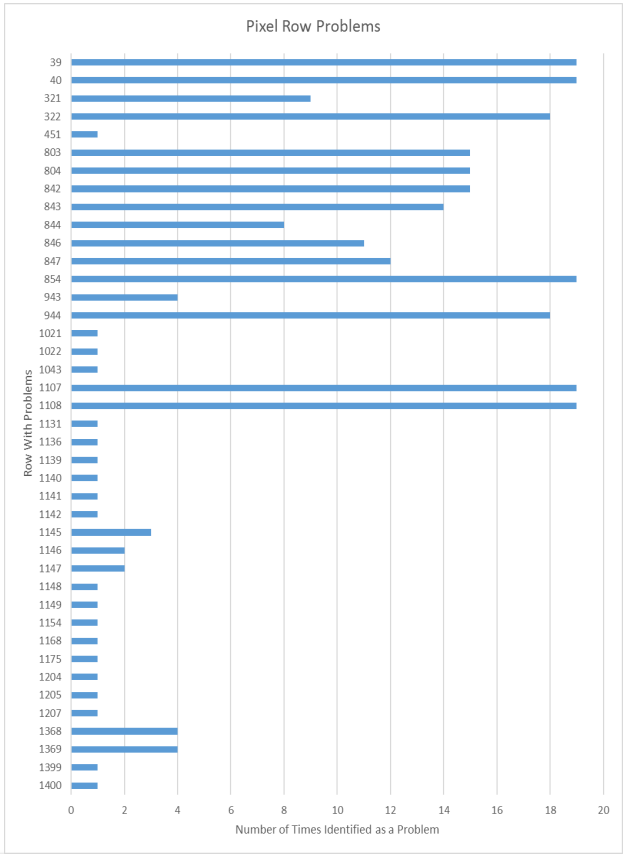

- For PSFs, smaller is better (indicates less blurring)

# Images from NII 1

- Images were encoded as .tif files
  - 16 bit unsigned integers for high dynamic range and no compression artifacts.
  - High vertical resolution.
  - Many bad detector rows
  - Fairly tight range of horizontal and vertical PSF widths over all images

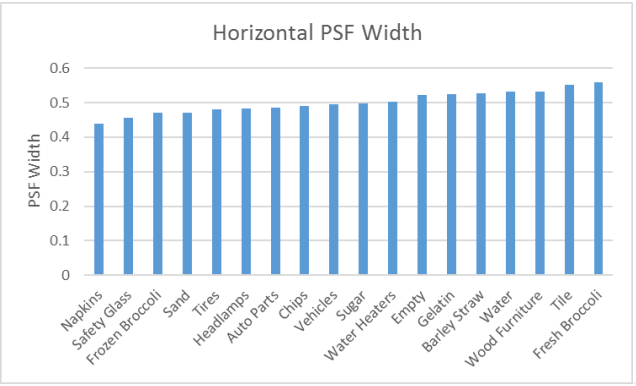


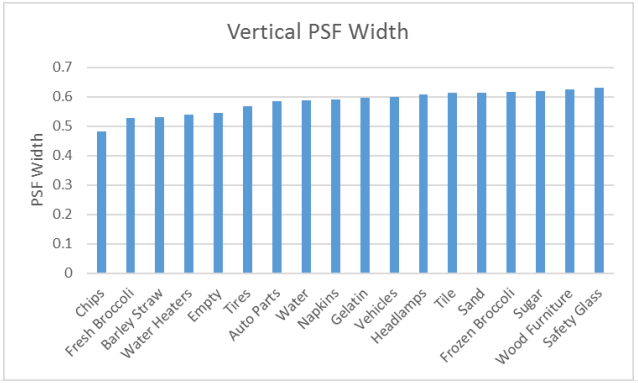



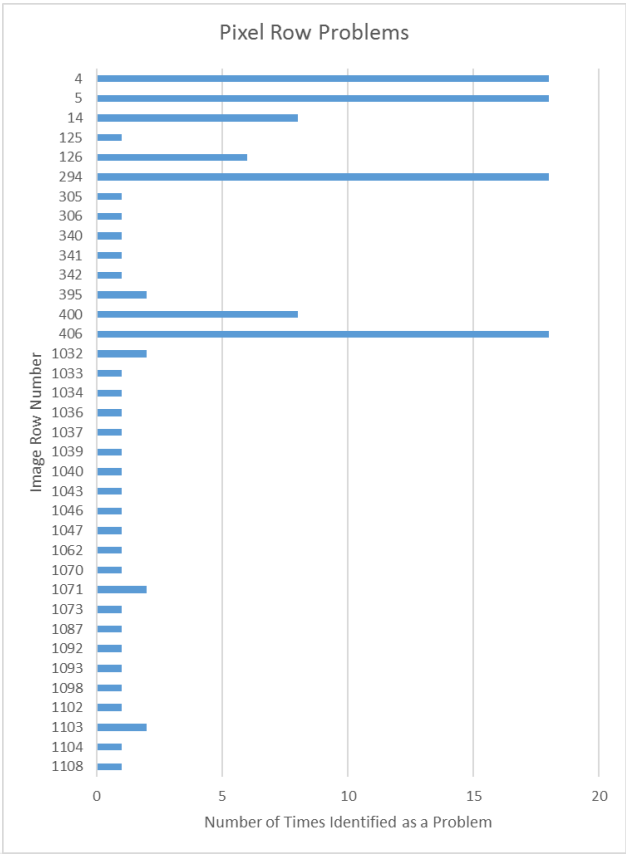



# Images from NII 2

- Images were encoded as .jpg files
  - 8 bit images with low dynamic range and compression artifacts
  - High vertical resolution
  - Fewer obvious bad detector rows, but may be hidden in jpeg compression.
  - Fairly tight range of horizontal and vertical PSF widths over all images



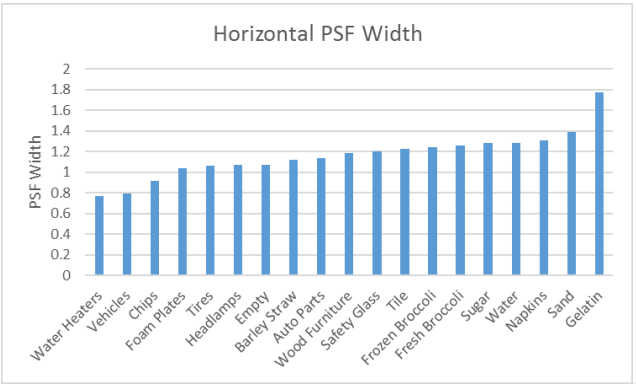



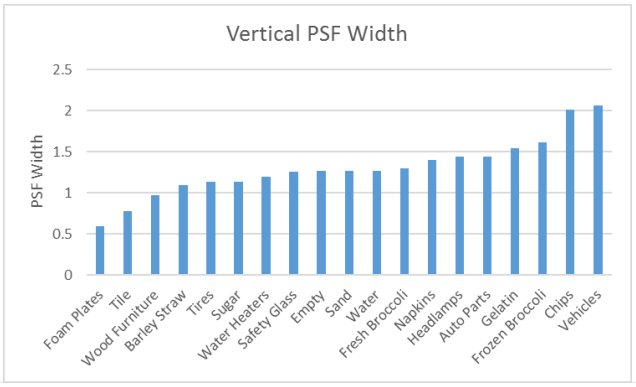



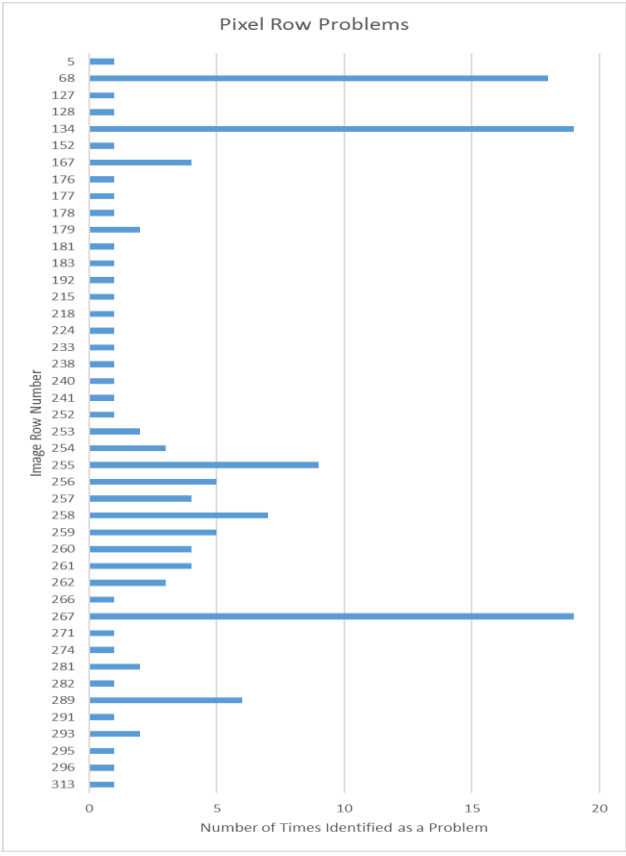
# Images from NII 3

- Images were encoded as .tif files
  - 16 bit images with high dynamic range
  - Low vertical resolution
  - Fewer obvious bad detector rows
  - Wide range of horizontal and vertical PSF widths over all images
  - Funky artifacts in almost half the images

    - We have added the ability to flag these problems

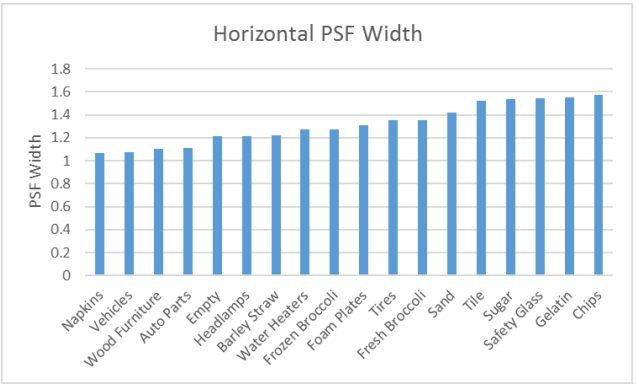


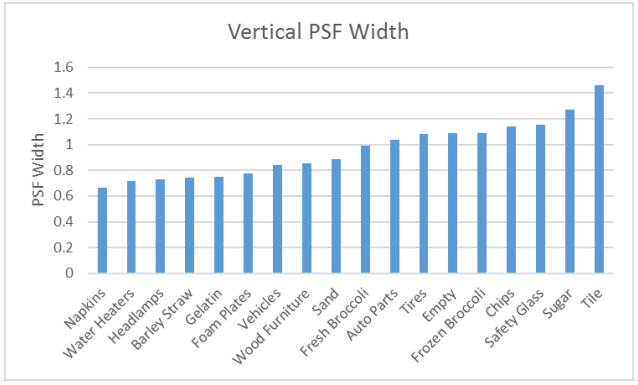



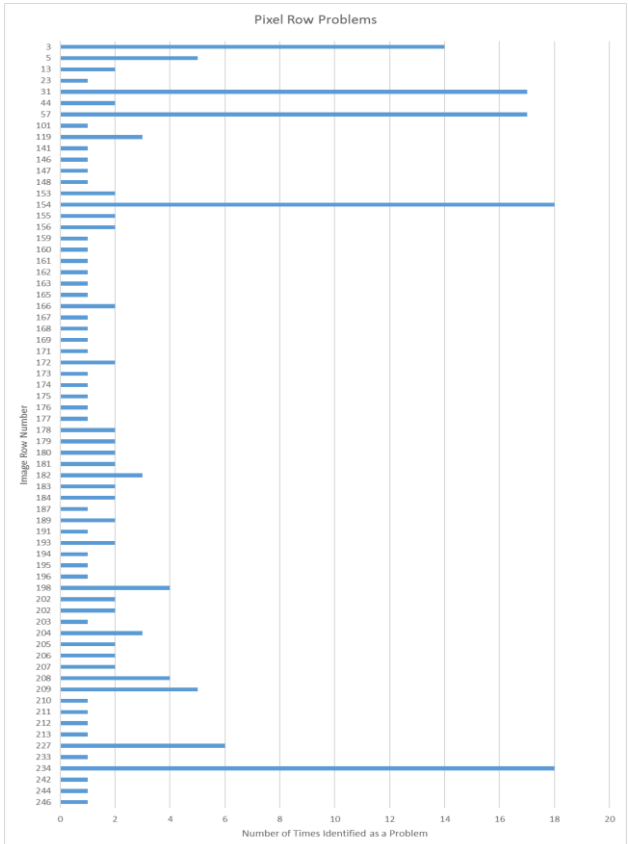



# Images from NII 4

- Images were encoded as .tif files
  - 16 bit images with high dynamic range
  - Low vertical resolution
  - Fewer obvious bad detector rows
  - Wide range of horizontal and vertical PSF widths over all images
  - Off axis imaging made it very difficult to find transitions for evaluating PSF
    - Noise level was very high

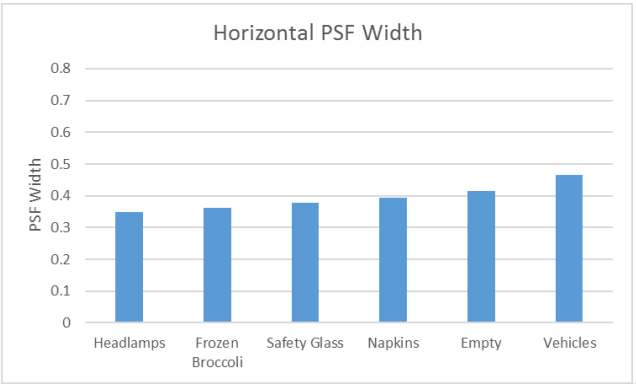


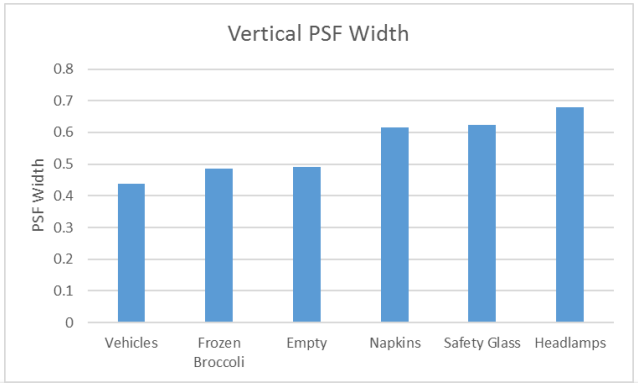



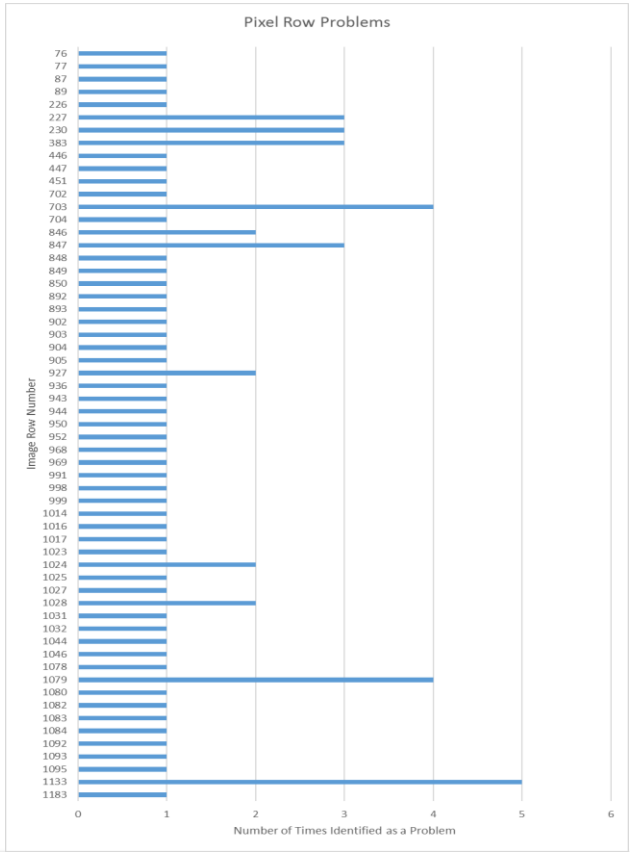



# Images from NII 5

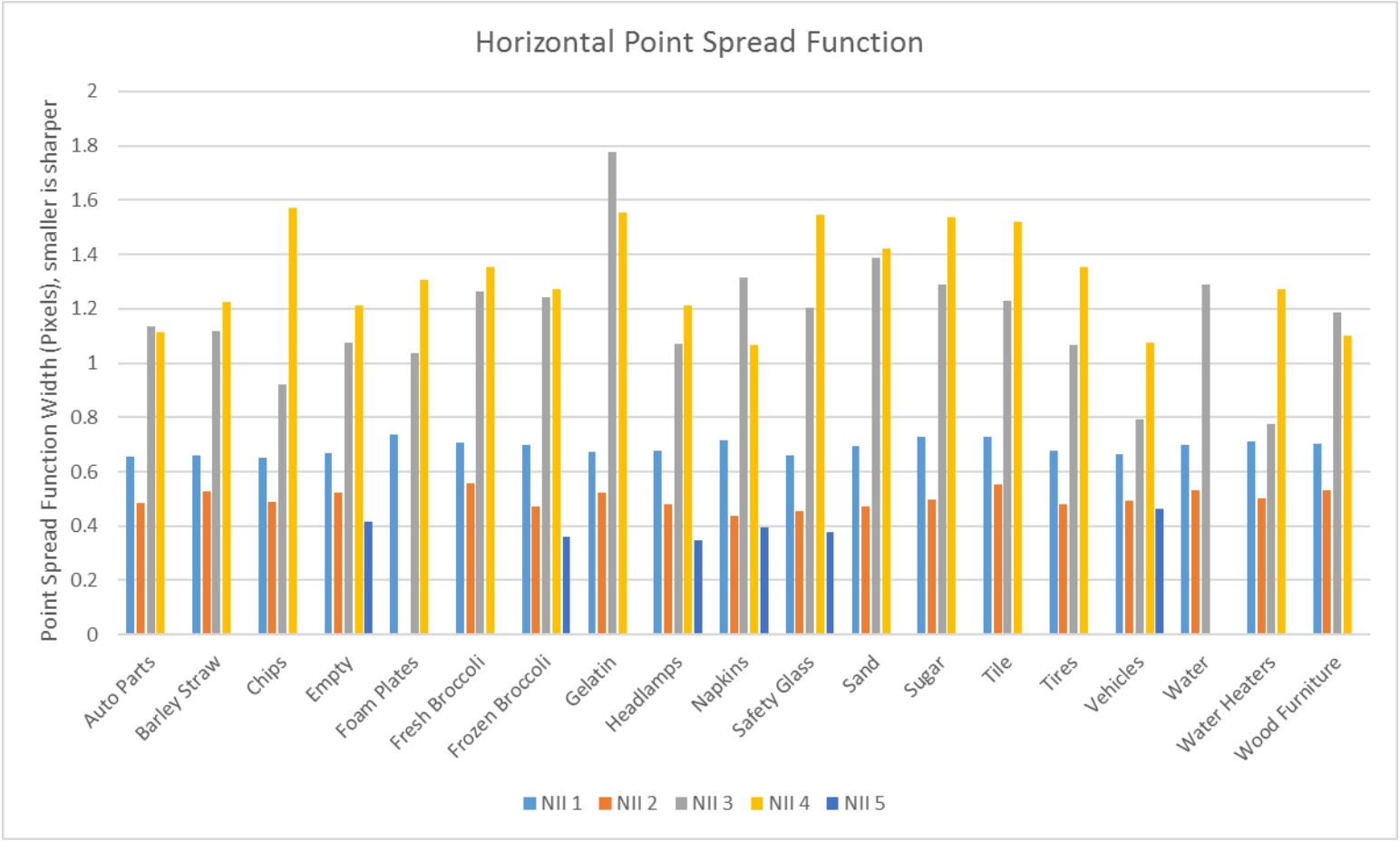
- Images were encoded as .jpg files
  - 8 bit images with low dynamic range and compression artifacts
  - High vertical resolution
  - Many images (13 of 19) were color mapped and not analyzed
  - Harder to choose bad detector rows
  - Very narrow PSFs – almost certainly due to compression artifacts



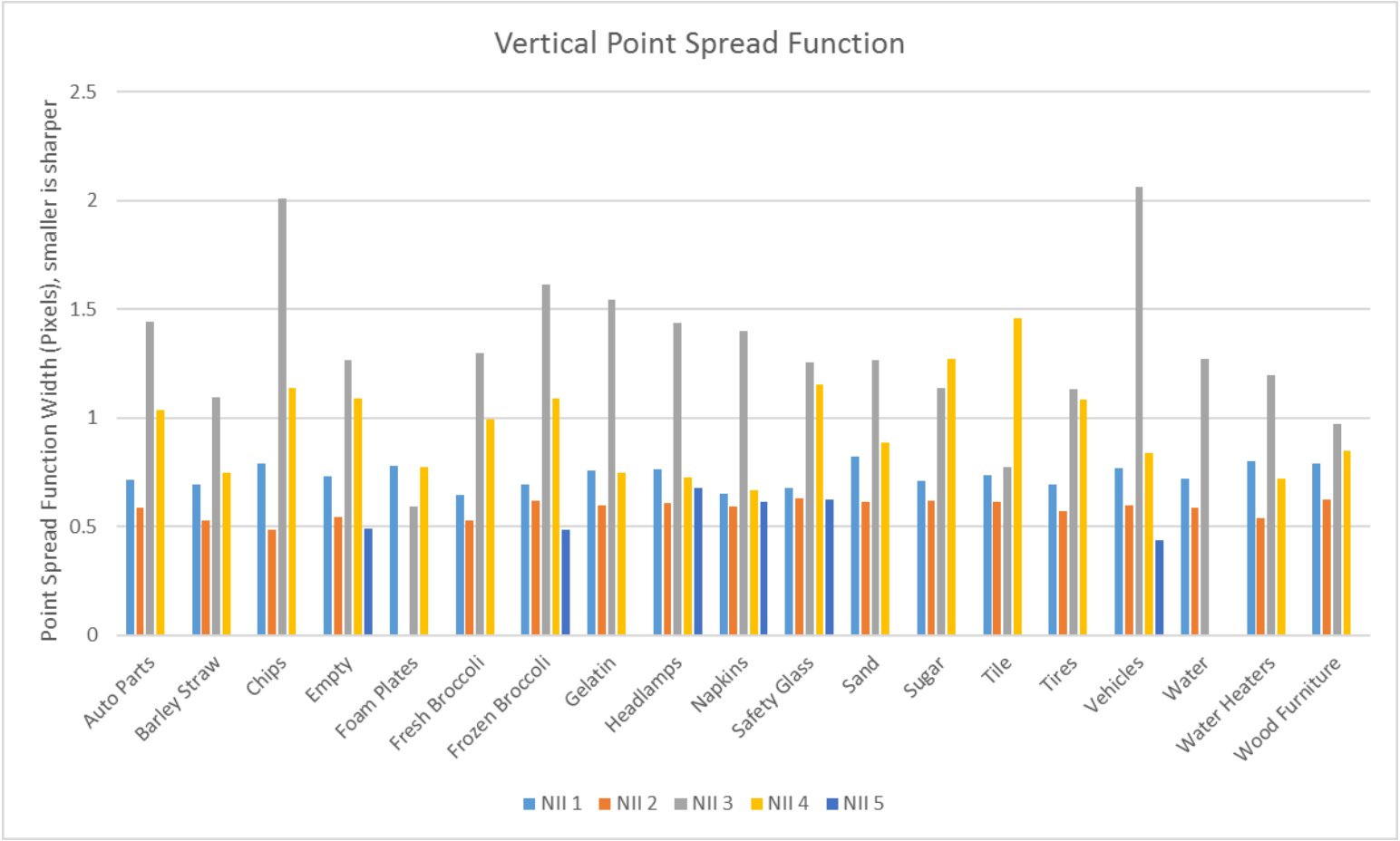



# Cross Cutting PSF Graphs: Horizontal PSF Widths




- Note, smaller PSF width values are better (if not an artifact of lossy compression, e.g. NIIs 2 and 5).

# Cross Cutting PSF Graphs: Vertical PSF Widths




- Note, smaller PSF width values are better (if not an artifact of lossy compression, e.g. NIIs 2 and 4).

# Future Work

- An intuitive and friendly graphical user interface should be built around the analysis software.
- Automate the analysis of directories of images.
- Incorporate analysis of additional imaging system artifacts that are not dealt with in the current analysis software, e.g.
  - Detection of dead image columns
  - Detection of nonuniform timing between image columns

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